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Improvements in or relating to toughened glass sheets and method for their production

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(73) Proprietor
**Triplex Safety Glass Company Limited,
Triplex House,
Eckersall Road,
King's Norton,
Birmingham,
B38 8SR,
England.**

(72) Inventors
Geoffrey Greenhalgh

(74) Agents
**Page White & Farrer,
27 Chancery Lane,
London,
WC2A 1NT.**

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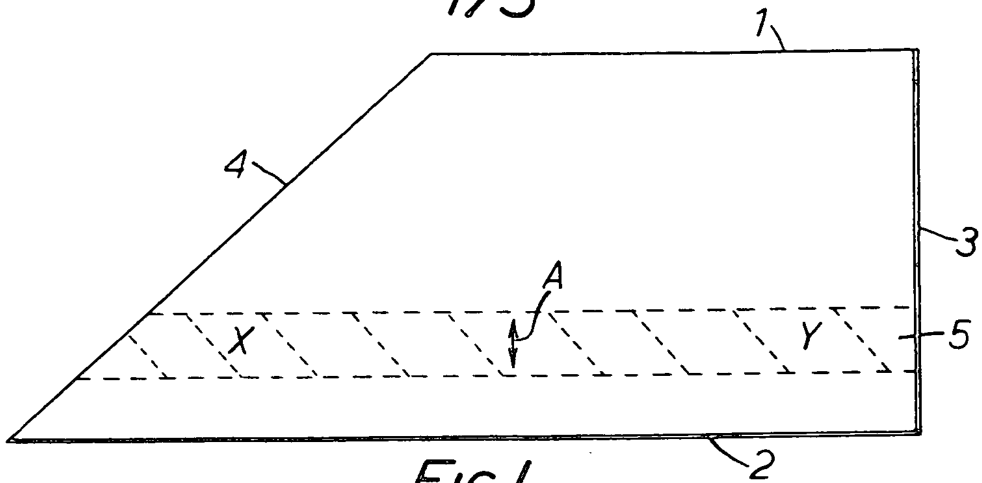

FIG. 1.

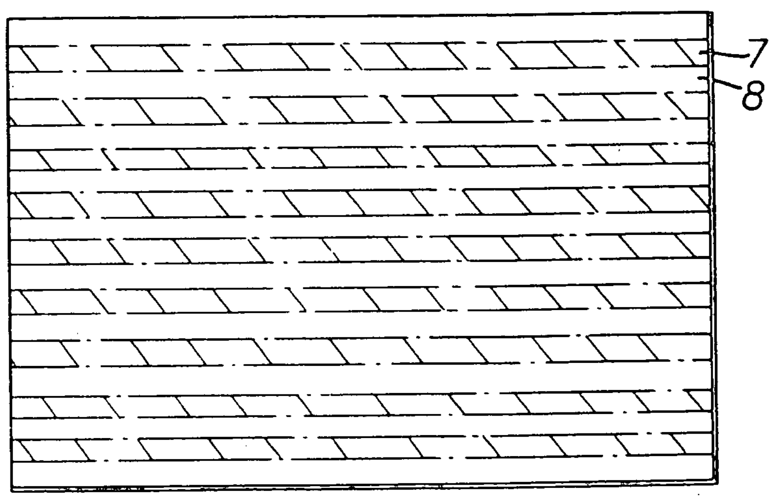

FIG. 2.

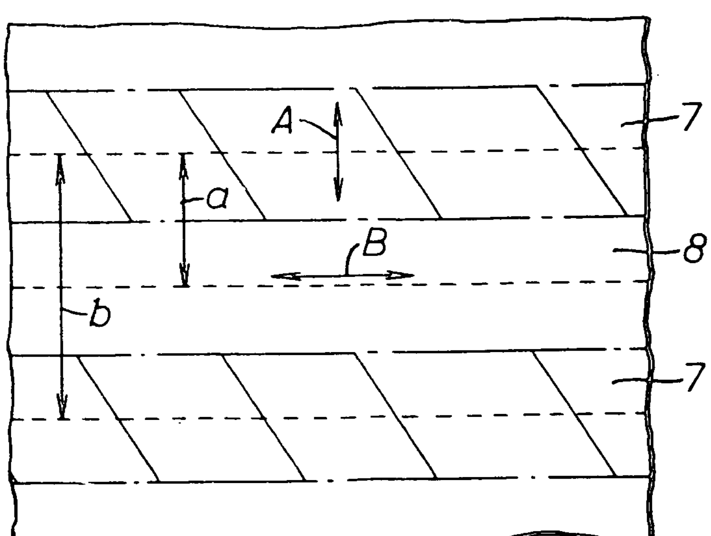

FIG. 3.

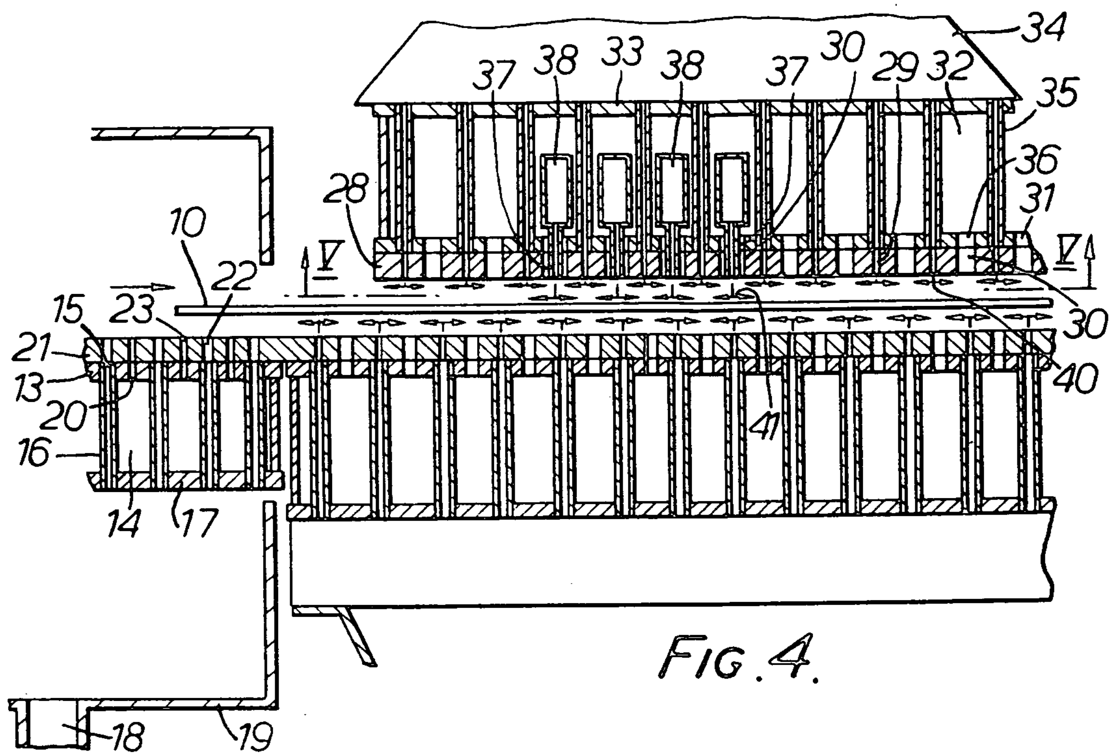
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FIG. 4.

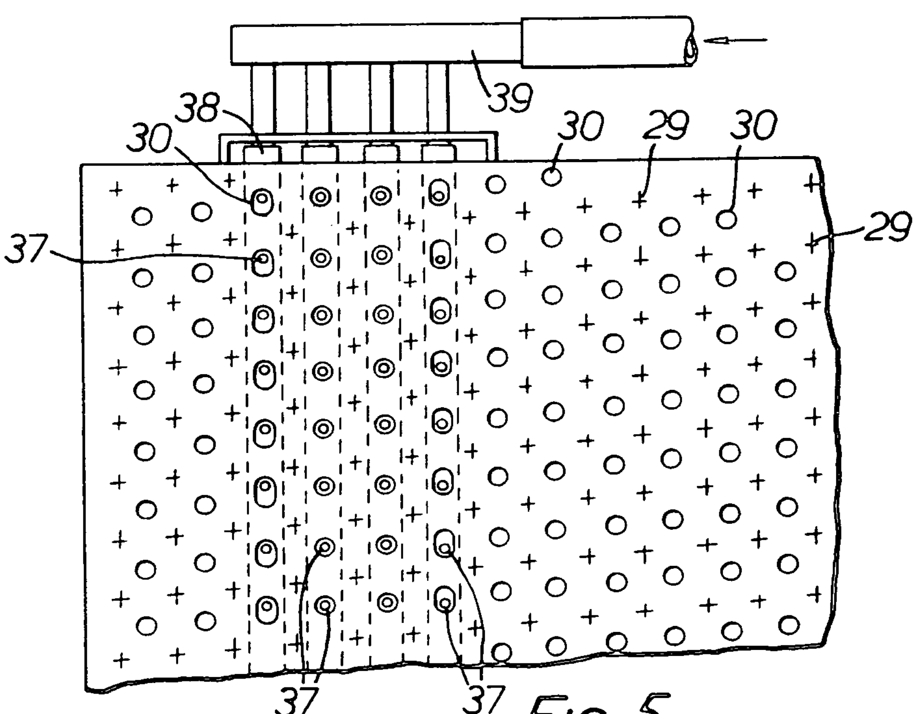
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FIG. 5.

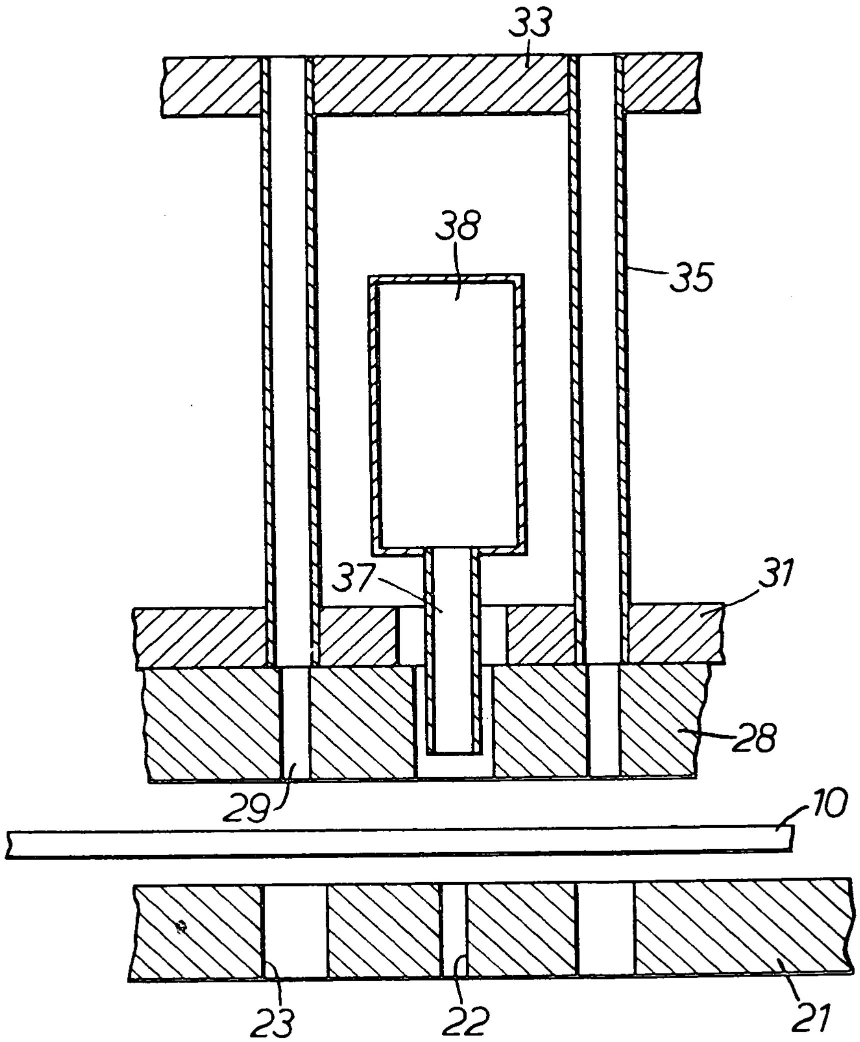

FIG. 6.

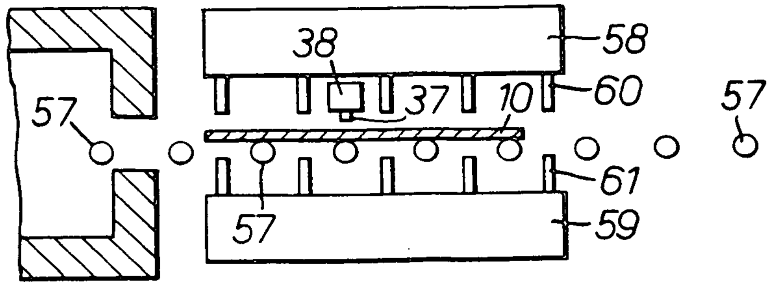

FIG. 7.

SPECIFICATION

Improvements in or relating to toughened glass sheets and method for their production

This invention relates to the toughening of glass sheets and in particular to the production of flat or curved sheets of thermally toughened glass to be used as motor vehicle side or rear windows.

In most countries there are official regulations specifying the fracture requirements for toughened glass sheets which are to be used as side or rear windows for motor vehicles.

Typically such regulations specify that the toughened glass sheets shall be fractured by localised impact at a defined position on the glass sheet, two particular positions being at the geometrical centre of the glass sheets and at a position adjacent the edge of the sheet. It is then required that areas of the fractured glass sheet should be selected where the particle count is a minimum and where the particle count is a maximum and limitations are placed on the minimum and maximum particle counts permissible in such areas. The minimum particle count permissible determines the maximum size of particles resulting from fracture so as to limit the danger of laceration by larger particles subsequent to fracture of the glass sheet in an accident. The maximum particle count permissible determines the minimum fineness of particles resulting from accidental fracture of the glass sheet so as to limit the danger of ingestion of fine glass particles. At present motor vehicle side and rear windows are made from glass at 4.0 mm to 6.0 mm thickness and can be uniformly toughened in the manner described above so as to meet official fracture requirements. For example glass sheets of thickness 4 mm and above meet the proposed E.E.C. standard referred to below if uniformly toughened to have a central tensile stress in the range 55 MN/m^2 to 59 MN/m^2. However in the interest of reducing weight there is now a trend towards the use of glass thinner than 4 mm, in motor vehicles for example glass of thickness in the range 2.5 mm to 4 mm.

In the draft standard under discussion by the European Economic Community (E.E.C.) it is required that the number of particles in any 5 cm × 5 cm square traced on the fractured glass, excluding a 3 cm wide band around the edge of the glass sheet and a circular area of 7.5 cm radius around the point from which fracture is initiated, should be 50 at the minimum and 300 at the maximum.

The proposed E.E.C. standard also has the requirement that the fractured glass sheet shall not contain any elongated particles with jagged ends of more than 6 cm in length, such particles being referred to as "splines".

British Standard No. BS 5282 entitled "ROAD VEHICLE SAFETY GLASS" is less restrictive than the proposed E.E.C. standard in that it specifies for glass less than 4 mm in thickness a minimum particle count of 40 in a 5 cm × 5 cm square may be permitted and the maximum permitted particle count in a 5 cm × 5 cm square may be 400. The British Standard also basically prohibits the presence of splines of more than 6 cm in length in the fractured test glass.

It had been found difficult to toughen thinner glass sheets to meet the official fracture requirements, this difficulty being particularly evident in a size greater than about 1100 mm × 500 mm this is about the size of the smallest vehicle rear window in current production. Many vehicle side windows are also of about this size or greater.

In our United Kingdom Patent Application No. 8995/76 (Serial No. 1512163) filed March 5, 1976 there is described and claimed a solution to the problem based on the discovery that glass sheets of the kind used as motor vehicle side or rear windows which are from 2.5 mm to 3.5 mm thick, particularly sheets 3 mm thick, could be toughened in a way which meets official fracture requirements such as the proposed E.E.C. standard, by quenching a distribution of regions of the glass sheet at a maximum rate so that interspersed regions of the glass sheet are simultaneously quenched at a minimum rate, regulating the maximum quenching rate and the size and spacing of the regions of the glass sheet which are quenced at the maximum rate such that an average central tensile stress is produced in the glass sheet within a range from a maximum of 62 MN/m^2 for all thicknesses of glass from 2.5 mm to 3.5 mm to a minimum of 56.5 MN/m^2 for 2.5 mm thick glass varying inversely with thickness down to the minimum of 53 MN/m^2 for 3.5 mm thick glass, and such that there is produced in the glass sheet a distribution of areas in which the principal stresses acting in the plane of the glass sheet are unequal, the principal stress difference in at least some of said areas being at a maximum in the range 8 MN/m^2 to 25 MN/m^2, the major principal stresses in adjacent areas in which the principal stress difference is a maximum being in different directions and the distance between the centres of such adjacent areas being in the range 15 mm to 30 mm.

In carrying out the method of the above mentioned patent application quenching was effected by directing quenching jets at the glass sheet, and imparting a vertical oscillation or a circular oscillation to the quenching jets to produce the required distribution of regions of the glass sheet quenched at a maximum rate. The quenching could also be effected by directing stationary quenching jets at the glass sheet to produce the required distribution of regions of the glass sheet quenched at a maximum rate.

Glass sheets for motor vehicle side windows in particular are often of irregular non-rectangular shape. Many side windows are for example of trapezoidal shape. The toughening of such sheets by conventional methods, particularly when the sheets are the thickness in the range 2.5 mm to 4 mm has produced a product which does not always satisfy the standards because of the production of splines in the fracture in localised areas of the sheet. This difficulty can arise even in the case of some small sized vehicle side windows because of their shape.

When the sheet is of trapezoidal shape for example the region of the sheet extending towards the narrowing, pointed end of the sheet is particularly prone to the production of splines when the glass sheet is

Figure 6 is a detailed view of part of the quenching station of Figures 4 and 5, and

Figure 7 illustrates the toughening of a glass sheet by the method of the invention while the sheet is supported on a roller conveyor.

Figure 1 illustrates a glass sheet, 3 mm thick for use as a motor vehicle side window. The sheet is of trapezoidal shape having two parallel sides 1 and 2. The trapezoidal shape of the sheet is further determined by a side 3 at right angles to the parallel sides 1 and 2 and a sloping side 4 leading from the shorter parallel side 1 to the longer parallel side 2.

In a particular example the length of the shorter parallel side 1 is 480 mm, the length of the longer parallel side 2 is 860 mm and the side 3 is 380 mm long.

The glass sheet is toughened in a manner which will be described so as to have a strip-shaped region 5 which is delineated in Figure 1 by dotted lines, and which has a higher central tensile stress than the central tensile stress of the rest of the glass sheet. The width of the region 5 parallel to the side 3 of the sheet may be 38 mm to 50 mm. The region 5 is adjacent the longer side 2 of the parallel sides of the sheet and is spaced from the side 2 by a distance of from 50 mm to 75 mm.

The glass sheet is toughened by the use of quenching gas flows in the manner which will be described with reference to Figures 4 to 6 to produce central tensile stress in the main body of the glass of 57 MN/m^2 and central tensile stress in the strip-shaped region 5 in the range 59 MN/m^2 to 62 MN/m^2, that is central tensile stress in the region 5 in the range from 2 MN/m^2 to 5 MN/m^2 greater than the central tensile stress in the main body of the glass.

In the strip-shaped region 5 the principal stresses acting in the plane of the glass sheet are unequal, with the major principal tensile stress acting across the strip 5 as indicated by the arrow A and with a principal stress difference, that is the difference between the major and minor principal stresses, in the range 12MN/m^2 to 16 MN/m^2.

The region 5 extends over two areas of the glass sheet indicated by the letters X and Y where, but for the production of the region 5, the glass sheets have been found to be particularly prone to the production of splines when the sheet fractures.

The provision of the strip of more highly toughened glass which has a central tensile stress from 2 MN/m^2 to 5 MN/m^2 greater than the central tensile stress in the main body of the glass with the principal stress difference of 12 MN/m^2 to 16 MN/m^2 ensures that splines are not present in this particular glass when fractured, particularly in the region X where the glass narrows towards its longer parallel side.

In some instances it is desired that the modified toughening stresses should cover regions of greater width than can be covered by a single strip-shaped region of maximum practical width and a plurality of strip-shaped regions of higher toughening stress are produced in the glass sheet. In the ultimate where the production of splines and the minimum and maximum particle counts in the fracture anywehre over the whole of the glass sheet has to be controlled, parallel strip-shaped regions may extend over the whole glass surface in the manner illustrated in Figures 2 and 3. Figure 2 shows the production of such parallel regions, indicated at 7, in a rectangular glass sheet but such a toughening pattern may be produced in any glass sheet for a motor vehicle side or rear window which is of an irregular non-rectangular shape.

The test glass illustrated in Figures 2 and 3 was a rectangular glass sheet 4 mm thick and of outer dimensions 450 mm to 600 mm. Nine parallel strip-shaped regions 7 of higher central tensile stress were produced in the glass sheet. Each of the strip-shaped regions is 25 mm wide and the regions 7 are spaced apart by regions 8 of lesser toughened glass which are 25 mm wide.

As shown in Figure 3 the distance *a* between the centre of each of the regions 7 and the centre of a contiguous region 8 of lesser toughened glass is also 25 mm. This distance *a* may be in the range 15 mm to 50 mm.

While the distance *b* between the centres of adjacent regions 7 is 50 mm in the embodiment described, this distance *b* may be in the range 30 mm to 100 mm. In the more highly toughened regions 7 the major principal tensile stress extends across the strip-shaped region as indicated by the arrow A. In the lesser toughened regions 8 the major principal tensile stress extends along the region as indicated by the arrow B. The major principal stresses in contiguous regions are therefore in different directions and the distance between the centres of contiguous regions 7 and 8 where the major principal stresses which are in different directions are a maximum, is in the range 15 to 50 mm.

The average central tensile stress of the glass sheet is averaged along any line extending parallel to the shorter sides of the sheet from one of the longer sides to the other longer side. Values of average central tensile stress and principal stress differences for four sheets of the kind illustrated in Figures 2 and 3 are set out in the following Table:—

temperature. The presence of each glass sheet advancing into the quenching station from the furnace generates a gaseous cushion between the sheet and the upper surface of the bed which provides both the required support for the sheet and a flow of chilling air against the bottom surface of the glass sheet. The advance of the glass sheet into the quenching station is by means of rotating discs, not shown.

In the quenching section there is a generalised flow of quenching gas contacting the upper surface of the glass sheet which gas flow has a substantially identical chilling effect on the upper surface of the glass as the chilling effect of the lower surface by the gaseous support. The gas flows on the upper surface are generated from an upper gas supply and exhaust equipment of identical construction to the base bed supplying gas to and exhausting gas from the gaseous support.

As shown in Figure 4 the upper part of the quenching station comprises a plate 28 of asbestos-based, heat-resistant material which has gas supply apertures 29 and gas exhaust apertures 30. These apertures are also shown in Figure 5. The plate 28 is fixed to an apertured base plate 31 of a gas exhaust chamber 32. The matching surfaces of the plates 28 and 31 are machined flat so as to be gas tight. The roof of the exhaust chamber 32 is a plate 33 which also forms the base of a plenum chamber 34 to which chilling air at ambient temperature id supplied. The chilling air passes through apertures in the plate 33 and is conducted down tubes 35 extending through the exhaust chamber 32 the lower ends of which tubes are fixed in the baseplate 31 of the exhaust chamber and communicate with the gas supply apertures 29 in the plate 28. The gas exhaust apertures 30 in the plate 28 are aligned with exhaust apertures 36 in the plate 31 so that gas can escape from above the glass sheet into the exhaust chamber 32 whose walls have apertures so that the exhaust gases can be collected and recirculated.

The hot glass sheet is subjected to the generalised quenching gas flows at the quenching station as it is advanced into the quenching station, and during its advance it is also subjected to one or more localised gas flows to produce in the glass the higher toughened strip-shaped region 5 of Figure 1 or the parallel strip-shaped regions 7 of Figures 2 and 3. The apparatus of Figures 4 to 6 is particularly adapted to produce the parallel strip-shaped regions, but can be regulated, as will be described to produce one region 7 only.

When passing through the quenching station illustrated in Figures 4 to 6, the upper surface of the glass sheet 10 is subjected to a rectangular array of gas jets which are spaced apart in rows transversely of the direction of advance of the glass with rows spaced apart in the direction of advance. The distribution of the gas supply apertures and gas support apertures in the plates 21 and 28 is slightly inclined to the direction of advance of the glass, as illustrated in Figure 5. The rectangular array of gas jets which are in line with the advance of the glass, is provided by an array of gas supply nozzles 37 which are connected in rows to ducts 38 located in the exhaust chamber 32. The nozzles 37 extends downwardly through specially enlarged gas exhaust apertures 30 in the plate 28.

One end of each of the ducts is connected to an air supply manifold 39 located outside the exhaust chamber alongside the quenching station.

In the embodiment illustrated there are four rows of nozzles 37 spaced apart at the same pitch as the gas exhaust apertures 30 in the direction of advance of the glass sheet. In Figure 4 the quenching air flows supplied from the gas release apertures 29 are illustrated by the arrows 40 and the localised gas jets directed at the upper surface of the glass are illustrated by the arrows 41. The mounting of the ducts 38 with their nozzles 37 is illustrated in more detail in Figure 6. The air supply to the manifold 39 is switched on when the glass sheet is passing beneath the nozzles 37, and the manifold 39 is connected through a pressure regulator to a solenoid operated spool valve of conventional design.

In one example of operation the compressed air supply switched to manifold 39 is at 690 kPa. The diameter of the bore of each of the nozzles 37 is 4.9 mm and the nozzle spacing is at 50 mm square pitch. The spacing of the ends of the nozzles from the upper surface of the glass supported on the gas cushion at the quenching station is 6 mm to 12 mm. As the glass sheet advances through the quenching station the gas flows through the apertures 22 and 29 produce the lesser toughened regions 8, while the parallel strip-shaped regions 7 of more highly toughened glass are produced by the supplementary action of the gas jets 41 on the upper surface of the glass. The effect of each line of gas jets lying in the direction of advance of the glass is cumulative and the glass sheet emerging from the quenching station has the required stress pattern described above with reference to Figures 2 and 3.

For some applications one transverse row of gas jets may be sufficient supplied by one row of nozzles 37 connected to a simple supply manifold 39.

When producing a single strip-shaped region 7 of more highly toughened glass as in the trapezoidal glass sheet of Figure 1, the sheet is oriented with its parallel sides lying in the direction of advance and one nozzle 37, or a line of nozzles 37 spaced apart in the direction of advance are provided to produce the single region 7 either by a strong quench from the single nozzle or by the cumulative effect of the line of nozzles as the sheet passes through the quenching station. The single nozzles 37 of the line of nozzles are so spaced from the driving discs which are engaged by the longer parallel side 2 of the sheet as to ensure the desired spacing of the region 7 from the side 2 of the sheet.

Figure 7 illustrates the toughening of a glass sheet which is being advanced on a roller conveyor comprising a series of horizontal rollers 57.

The conveyor carries the glass sheet through a heating furnace to a quenching station where the rollers carry the glass sheet between upper and lower blowing boxes 58 and 59. The box 58 has an array of blowing nozzles 60 which point downwardly towards the roller conveyor so as to direct generalised

14. A method of producing a glass sheet according to claim 6, and substantially as hereinbefore described with reference to Figures 4, 5 and 6 of the accompanying drawings.

15. A method of producing a glass sheet according to claim 6, and substantially as hereinbefore described with reference to Figure 7 of the accompanying drawings.

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